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AIRCRAFT SIMULATOR DATA REQUIREMENTS STUDY

EXECUTIVE SUMMARY

SYSTEMS RESEARCH LABORATORIES, INC.
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JANUARY 1977

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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The United States Air Force had encountered difficulties involving the availability, quality, and format of air weapon system design data required for the acquisition of simulators. In view of the increasing importance of modern digital computer-driven flight simulators in providing the required training, both for initial qualification and for the maintenance of readiness, it was determined that an up-to-date standard to identify the data required by simulator manufacturers was needed. This standard would then be included in the development

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and acquisition contracts for future weapon systems to provide for the timely supply of the requisite data.

Systems Research Laboratories, Inc. was selected to perform a study of the simulator data requirements, resolve any difficulties incident to the timely supply of that data, and prepare a General Requirement for the acquisition of that data in future contracts. The study was conducted by surveying simulator manufacturers and simulator acquisition activities to determine the problems and requirements, then surveying aircraft, avionic systems, and engine manufacturers to determine data availability, problems in satisfying the requirements, and suggestions for alternate approaches.

As a result of this study, a proposed General Requirement was prepared which could be included in future weapon system procurement contracts to provide for the timely supply of the data required for simulator development. In addition to this "Data Specification," certain other actions are required to make the system work.

1. Order the data when the aircraft is ordered.
2. Place simulator data at a high enough precedence to ensure compliance.
3. Make certain that simulator data requirements are included in the procurement contracts for GFE items.
4. Have simulator data delivered to the Government.
5. Have an initial data package based on the best data available, probably wind tunnel, bench test, and engine test-stand supported estimations, delivered after the aircraft design freeze and before announcing the simulator development competition.
6. Have the initial data package updated at specific block intervals until all data is based on flight test results or equivalent "hot bench" data.
7. Task the Air Force Flight Test Center to make engineering simulations of each new aircraft development program and to derive the handling qualitites and performance parameters from flight test data for the use of the simulator manufacturer. Make this an early item in the flight test program so that the simulator can be in operation at the operational command in time to support the receipt of the first aircraft.
8. Task AFFTC to supply a qualified test pilot current in type and a flight test engineer to assist in the simulator development from the initial contract award through acceptance testing.

Other recommendations for further studies to resolve certain simulation technical problems and to reduce the cost of simulators are included in the report.

FOREWORD

This report was prepared by Systems Research Laboratories, Inc. of Dayton, Ohio, under Contract F33615-76-C-0106. The work was performed under the direction of the Aeronautical Systems Division, Deputy for Development Planning, Wright-Patterson AFB, Ohio. Mr. Richard E. Worthey was the ASD Project Manager.

The program was conducted from 1 May 1976 through 15 December 1976. Mr. Harold L. Iffland and Mr. George A. Whiteside were the SRL principal investigators.

The authors wish to thank the representatives of the companies and Government activities surveyed during this investigation for their cooperation and assistance, without which this study would have been impossible to perform.

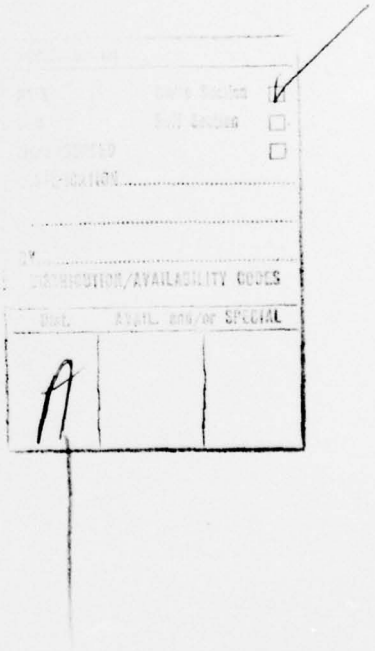

TABLE OF CONTENTS

SUMMARY

The United States Air Force had encountered difficulties involving the availability, quality, and format of air weapon system design data required for the acquisition of simulators. In view of the increasing importance of modern digital computer-driven flight simulators in providing the required training, both for initial qualification and for the maintenance of readiness, it was determined that an up-to-date standard to identify the data required by simulator manufacturers was needed. This standard would then be included in the development and acquisition contracts for future weapon systems to provide for the timely supply of the requisite data.

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SECTION I

INTRODUCTION

The Aircraft Simulator Data Requirements Study was sponsored by the Aeronautical Systems Division, Air Force Systems Command, United States Air Force, under the supervision of the Deputy for Development Planning, ASD/XRU. Systems Research Laboratories, Inc. performed the study under Contract F33615-76-C-0106. The period of performance was from 1 May 1976 through 30 January 1977.

SECTION II

METHODOLOGY

The approach employed in this study was to first survey a selected list of simulator manufacturers to determine their data needs and any problems encountered in obtaining data, then to survey a selected list of aircraft manufacturers to determine their ability and willingness to supply the data and to define any alternate suggestions they might offer, and, lastly, to resolve any outstanding problems and prepare a data specification which would be included in future weapon systems acquisition contracts to provide for the timely delivery of the data needed to develop simulators and trainers of less complexity. Ways to improve the data acquisition process were studied.

SECTION III

RESULTS

Although the simulator manufacturers consider that data problems lie at the root of most of their serious problems, both the simulator and aircraft manufacturers believe that an inexpensive solution is readily available: order the data with the airplane and enforce delivery.

The simulator point of view is that the data package they obtain does not represent the airplane, and the acceptance test procedure does not agree with the data package which, when coupled with the very high accuracy replication of the aircraft required over the entire flight envelope (and beyond), causes confusion, excessive rejections, and expensive rework. Another point that was raised as a major cause of expense and the cause of some data problems is the very large number of malfunctions and abnormal operations which must be simulated accurately.

The simulator manufacturers do not insist on having the data in any given format; they can use it in the same format the aircraft manufacturer requires if the conditions, etc. are properly annotated. The data they need generally exists somewhere in the aircraft manufacturer's engineering department even though it is not formally reported. The problem is that many times the simulator manufacturer is kept at arm's length and prevented from talking directly to the engineers who prepared the aircraft data, hence the man who has the required information, or an acceptable substitute, is never found.

Aerodynamic data estimates based on wind tunnel test results are available well before the simulator manufacturer needs them. These are adequate to carry the simulator design forward to an operating machine. However, before the simulator can be accepted as ready for training, it will need to incorporate aerodynamic data derived from flight test results. This data package update has not been available when needed.

System data based on engineering estimates are available on time. Many of these systems can be updated to final form in "hot bench" tests,

the results of which are also available on a schedule to support the simulator requirements. Some avionics systems require flight test results to finally refine the cues, etc. to be simulated. The comments above relative to flight test aerodynamic data apply to these data as well.

For electronic warfare trainers the design frequently requires intelligence data. This creates a special problem, in addition to the clearances required, in that these data are collected by many different agencies and are stored in many different repositories and under different descriptors. Without a Kilting file, the manufacturer is in a poor position to even guess where to start. There is also the problem that a great deal of these data are conflicting. What the manufacturers need is for a single point in the Government to collect the data, resolve the differences, and "buy off" on the data package. They also need the services of a "certified user expert" in the early stages of development of a trainer to define the subtle changes in visual and aural presentations that are important for training electronic warfare officers.

For the propulsion system, very complete test stand, steady state, data are available well before the need date. Installed data, air starts, dynamic responses, etc. are generally not available on time. Of course some of it would have to wait for flight tests. A great deal of the detailed design-type data that have been requested, and in some cases caused trouble, were required solely to simulate failures and abnormal operation. The accuracy of simulation of propulsion system performance under all conditions, which is being attempted, presents the fundamental problem that the number of variables to be accommodated is so great that the resulting math model requires far more computer capacity than the simulator manufacturers can afford. A change in the philosophy of malfunctions and abnormal operation would help solve this problem.

The trend in modern weapon system design is to integrate avionics systems and other mission equipment and have them operate through a central computer complex. Many functions are multiplexed on each data channel.

The pilot (operator) does not "talk" directly to the sensors, nor do the sensors present outputs directly to the operator in normal operation. The entire communication is carried out through a central processor which may vary the operator's commands before sending them to the sensors, and may perform operations on the sensor outputs before presentation to the operator. The operations to be performed by the central processor, the computer program, are established by tactical program tapes which are read into the processor from time to time. In effect, the tactical program tape configures the system.

Tactical program tapes are very tedious and time consuming to prepare and debug. If the simulator manufacturer has to take this tape and go through a long translation and debugging process before he can use it, the simulator configuration will of necessity lag the configuration of the operational aircraft. Since this lag could easily be one year or longer, it is apparent that the simulator must be able to use the same tactical tapes as the operating aircraft.

Simulation of these complex central computer avionics systems requires essentially a duplication of them. There are problems in using the flight qualified hardware relative to cost, computational speed, and in some cases durability. Developing a non-flight qualified equivalent system is a possible solution. The true life-cycle costs of the two approaches appear to favor using the flight qualified central computer and multiplexing equipment. The simulator computer will have to supply sensor outputs to the central processor and perform the calculations for all other simulations that do not depend on the central processor.

The simulator manufacturers want to talk directly to the engineers of the vendors and subcontractors of the aircraft prime contractors for the same reasons they want to talk directly to the prime contractor's own engineers. No blanket authorization to do this is agreeable to the primes. They want to receive the requests for information, and in case a visit to a vendor is required, they will make the necessary arrangements. A great

deal of potential problems with vendor data are overcome by the simulator manufacturer's willingness and capability to use functionally equivalent data in lieu of the actual data.

The physical data concerning the aircraft (e.g., crew station drawings and arrangement sketches, mock up photographs, maximum envelope, weight, moments and center of gravity) are available on the required schedule. In general the simulator manufacturers considered these data to be adequate; however, the Air Force Flight Test Center personnel pointed out that they find the weight and moment data to be significantly in error from time to time. The simulator, of course, will not handle correctly unless this information is accurate. Possibly in the past, aerodynamic data were blamed, particularly aileron effectiveness, when the real problem was an error in the roll moment of inertia.

The aircraft manufacturers were quick to point out that, although they were confident that they could satisfy all the simulator data requirements if the data were ordered with the airplane, this did not extend to cover Government-furnished equipment. The Government will have to provide for the acquisition of that data.

The simulator manufacturers point out that the data requirements must be contracted for by an activity with enough "clout" to enfore compliance. Primarily for this reason they do not like to develop simulators as a subcontractor to the aircraft prime contractor. The aircraft manufacturers stated that simulator data would have to be placed at a high enough priority to insure the assignment of adequate assets early in the program, a position which agrees with that held by the simulator manufacturers.

In order to procure simulator required data in an orderly program at minimum cost, it is essential to order this data in the initial development order for the weapon system or GFE item. This permits the aircraft prime to provide for the needed data from his vendors while he is still in a competitive situation, and permits all of them to set aside the data as they go along rather than going back later and recreating it. The initial

data package should not be scheduled for delivery, however, until after design freeze of the basic item.

It was pointed out that many of the crew station components, such as panels, levers, pedals, furnishings, etc., which are required to be in the simulator are long lead items early in the production program of an aircraft. The lead time is such that it is not possible to accommodate the simulator requirements after the simulator is placed under contract. If a few extra of these items were ordered in the initial contract and scheduled for early delivery, they could be supplied for the simulators or, if the simulator manufacturer does not want them, scheduled back into the production line.

The subject of project pilots and project crew members received quite a bit of discussion. The project crew members bring in operational employment information, as was mentioned earlier. These discussions and understandings are required early in the program, as well as later on when actual displays and aural presentations are available.

The project pilot should be a qualified test pilot who is current in the aircraft. The availability of such a pilot is not a substitute for a good data package; he supplements it. He is needed early in the program to help the simulator manufacturer understand the handling characteristics of the aircraft; he is invaluable during the simulator debugging period to assess the flying qualities of the simulator, determining not only what aspects of simulator performance are unlike the airplane and, more importantly, why.

The instructor's role in the training objective was repeatedly brought up. The decisions as to what role the instructor is to play, what functions he will control and which will be automated, must precede the design of the simulator and, to a significant extent, drives the design. This is an area that should be independently studied, and possibly would yield large savings in acquisition and instructor training costs through modularization and standardization.

SECTION IV

DATA ACQUISITION RECOMMENDATIONS

Implementation of the recommendations contained herein should provide the required data for the development of simulators at minimum cost and on a schedule such that the simulator can be on-site, ready for training before the first production aircraft is delivered to the operating command.

a. Order data for a full mission simulator in the initial aircraft acquisition contract.

b. Order simulator data in the initial contract (with each source for many items) for the acquisitions of equipments to be incorporated in weapon systems as GFE.

c. Schedule delivery of these data as late as possible, consistent with the simulator procurement and never before the design freeze of the item.

d. Require that the manufacturers involved keep the initial data package updated as changes are made to the equipment or more accurate data become available.

e. Have the initial data package delivered to the Government, make it available for review by prospective simulator bidders, and deliver it to the selected simulator manufacturer.

f. Make the initial data package the simulator specification baseline.

g. Require use of the on-board computer and tactical program tapes in the simulators of aircraft that have a central processor(s) avionics system such as the F-16.

h. Make the delivery of simulator data a program control milestone in the aircraft acquisition contract such that the aircraft program cannot proceed beyond that milestone until the data package is delivered.

i. Procure a few selected crew station parts for use in a simulator in the initial aircraft production contract, and schedule delivery of them in time to support possible simulator requirements.

j. Task the AFFTC to develop and supply handling quality derivatives and performance parameters based on flight test results. This should be done for each new Air Force aircraft as early in the flight test program as possible.

k. Task the AFFTC to supply a flight test engineer and qualified test pilot experienced in the subject aircraft to provide technical guidance and assistance to the simulator manufacturer during his development program.

SECTION V
RECOMMENDATIONS FOR FURTHER STUDY

During the course of this investigation, information was developed which forms the basis for the following recommendations for additional study.

a. AFFTC has from time to time encountered a marked difference in the number of tasks a pilot can accomplish in a given time in a simulator and in an aircraft, even an RPV. Further study of this "time compression" effect is necessary so that it can be fully defined and considered in the simulator designs.

b. In order to define the roles of simulators and through them the equipments and performance requirements necessary, a series of mission and systems analyses should be conducted of the training missions comprising the total Air Force requirement.

c. Following the analyses of (b) a series of simulator cost effectiveness trade-off design studies should be undertaken to optimize satisfying the defined requirements.

d. Conduct a study to determine the true reasons for the low exploitation of simulator capability in the past and derive corrective action.

e. Develop and implement a program to verify that the simulators in the field continue to perform with the necessary fidelity.

f. Conduct a cost versus effectiveness study of life-of-type simulator maintenance approaches and implement the appropriate method.